

Comparison on Different Evaluation Methods of Heavy Metal Pollution----- A Case for K1 Columnar Samples of Yalu River Estuary Watercourse

H.J. Li¹, Y. Cheng^{2*}, J.X. Wang¹, R.X. Li¹, Y.J. Ma¹

¹College of Urban Construction, Easten Liaoning University, Dandong 118003, China

²Planning and Design Institute, Easten Liaoning University, Dandong 118003, China

*yancheng60@126.com

Abstract

Heavy metals were determined in columnar sediment samples of the Yalu River estuary watercourse. The environmental status was assessed by using the pollution load index, geologic cumulative index, potential ecological harm index and Nemerow index. It is shown that the geologic cumulative index and Nemerow index show a low level of heavy metal pollution indicating that the pollution of K1 columnar samples is not serious. The results of the ecological risk index and the pollution load index are consistent by indicating a medium pollution degree of columnar sediments of the Yalu River estuary watercourse.

Keywords

Heavy Metals; Pollution Evaluation; Yalu River

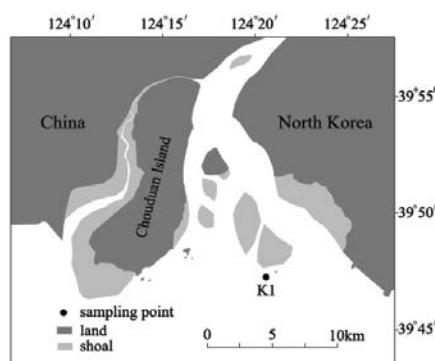
Introduction

Different methods concerning the environmental status of coastal areas are developed using different evaluation indexes or tests such as the Index of Geo-accumulation, comprehensive pollution index, potential ecological risk index, pore water toxicity test, biological tissue residue detection, a benthic evaluation method (5, 6). The background level of each element is important for the calculation of most part of these indexes. Four different indexes were used in this study to evaluate the environmental pollution of the shallowness of the Yalu River. The background values of heavy metals of shallow sea of China were used during the index calculation.

More than 60 years, all kinds of poisonous and harmful industrial waste water have been discharged into the Yalu River caused a certain degree of pollution on the Yalu River estuary waters [3-4]. But how far pollution, what more objective evaluation method is worth in-depth study. The author will use K1 columnar sediment samples of the Yalu River estuary watercourse to compare the difference between the different evaluation methods, to provide the reference for the development of social economy and ecological planning of the Yalu River estuary.

Materials and Methods

Materials



On the shallows of the Yalu River watercourse used vertical intubation in water in August, 2014, used PVC tube inserted into the sediment, got 108 cm columnar samples. Sampling point coordinates, Latitude: E 30 '124 ° 20', N39 ° 48 '01.

Determination of Heavy Metals

Cu, Pb, Zn, Cd, Cr and Ni elements concentration are measured by the plasma emission spectrometry and Hg content is measured by cold atomic fluorescence method. Relative standard deviations of them were less than 5%.

Evaluation Methods

There were many pollution evaluation methods for sediment heavy metals in estuary. They mainly include Index of Geoaccumulation method, comprehensive pollution index method, potential ecological risk index method, pore water toxicity test method, biological tissue residues detection method, benthic evaluation methods and data calculation method (5, 6). As a result of different research angle and purpose and choosing different background values, these four kinds of methods were used to evaluate environmental pollution, as the shallow sea background values of heavy metals in China.

1) Ecological Risk Index (Ri)

RI was calculated as the follow:

$$RI = \sum T_r^i \times C_s^i / C_n^i \quad (1)$$

Where T_r^i is the toxic response index for heavy metals i . T_r^i values for Cu, Pb, Zn, Cd, As, Hg, Cr and Ni see table 1. C_s^i is the measured concentration of metal i at sampling sites, C_n^i is the background values of heavy metals i in sediments. [5, 12, 13, 14]

2) Index of Geoaccumulation

The calculation formula is as the following:

$$I_{geo} = \log_2 [C_s^i / (k C_n^i)] \quad (2)$$

In the formula: C_s^i is the values of heavy metals i measured in sediment; C_n^i is the background values of heavy metals i measured in sediment, k is a constant joined in rock forming movement background value change, average value is 1.5 [5,13].

3) Pollution Load Index

The calculation formula is as the following:

$$Ipl = \sqrt[n]{F1 \times F2 \times F3 \times \dots \times Fn} \quad (3)$$

In the formula: $Fi = C_s^i / C_n^i$. C_s^i is the peak values of heavy metals i measured in sediment; C_n^i is the background values of heavy metals i in sediments [5].

4) Nemerow Index

The calculation formula is as the following:

$$P = \frac{\sqrt{(P_{\max})^2 + (P_{\text{men}})^2}}{2}$$

In the formula: $P_i = C_s^i / C_n^i$. $p_{\max}$ is the ratio of the maximum and background value of the pollution factor and pollution index; p_{men} is the ratio of average pollution index and the background values of each pollution factor index.

Background Value and Evaluation Standards

Chinese sea background values of heavy metals and toxic coefficient in Table 1.

TABLE 1 THRESHOLD CONCENTRATION OF GEOCHEMICAL BACKGROUND VALUE AND BIOLOGICAL EFFECT

Heavy metal element	Cu	Pb	Zn	Cd	As	Hg	Cr	Ni
Chinese sea background values of heavy metals ^[10] (mg/kg)	15	20	65	0.065	7.7	0.025	60	24
Toxic coefficient ^[11]	5	5	1	30	10	40	2	5

TABLE 2 FOUR EVALUATION METHODS OF EVALUATION STANDARD^[5-9]

All kinds of factor, index	no	slight	medium	Medium-strong	strong	stronger	strongest
RI		≤150	150-300			300-600	≥600
I_{geo}	0	0-1	1-2	2-3	3-4	4-5	>5
I_{pl}	<1		1-2		2-3		≥3
P	<1	1-2.5		2.5-7			≥7

Results and Discussion

Heavy Metal Content and Statistical Characteristics of K1 Drilling

As shown in Table 1, it is the statistical results of heavy metals of drill K1 Cr, Ni, Cu and Zn, Cd, Pb, As, Hg. The average content of heavy metals were 41.46 (Cr), 17.97 (As), 16.08 (Cu), 73.05 (Ni), 0.18 (Pb), 33.61 (Cr), 6.03 (Zn) and 0.087 (Hg)mg/kg coefficient of variation reflects a statistic of degree of variation. To some extent, it can reflect anthropogenic effect of sample. The higher the coefficient of variation is, the more significant anthropogenic effect about the heavy metal content of the sediment is [9, 10, 11]. The coefficients of variation (CV%) of As, Cd, Ni and Cr are small (CV% < 25) and on the border of medium values (CV% = 25 – 75) for Cu, Pb, Zn and Hg indicating a relatively stable concentration level of these elements in columnar sediment samples of Yalu River .

TABLE 3 STATISTICAL DATA OF HM CONTENT IN K1 COLUMNAR SEDIMENT SAMPLES

Elements	Variable					
	Minimum*	Maximum*	Average*	STDEV	CV %	max/min ratio
Cd	24.67	55.85	41.46	8.46	20	2.25
As	12.12	24.56	17.97	3.17	18	2.03
Cu	8.09	24.34	16.08	4.27	27	3.01
Ni	49.06	98.45	73.05	12.22	17	2.01
Pb	0.12	0.28	0.18	0.05	26	2.34
Cr	25.23	43.16	33.61	4.29	13	1.71
Zn	3.7	9.84	6.03	1.66	28	2.66
Hg	0.032	0.142	0.087	24.05	28	4.46

Note: * mg/kg, DW.

Order of variation of heavy metal element are: Hg=As> Cu> Cd> Cr> Ni> Zn> Pb. Therefore, from the point of coefficient of variation, Hg and As are serious polluted by man. The ratio of the maximum and the minimum of Hg is 4.46 times. The ratio of the maximum and the minimum of Cu is 3.01 times. The ratio of the maximum and minimum of other heavy metal elements is less than 3.

K1 Drilling Calculation Results of Heavy Metal Pollution in Different Evaluation Methods

K1 drilling calculation results of heavy metal pollution in different evaluation methods are known in Table 4.

The index of Geoaccumulation (IG) values of most of elements (As, Cu, Ni, Cr and Zn) indicated no pollution

status. The IG values of Cd and Pb indicated slight pollution status. Only the IG value of Hg indicates the medium pollution status of K1 columnar samples. The pollution of Pb mainly comes from the impact of human activities.

According to Nemerow index, Ni, Cr and Zn belong to no pollution state; As and Pb belong to the mild pollution state; Cu and Hg belong to the moderate pollution state.

Ecological risk index is 251.1, belongs to the moderate pollution. Pollution load index is 1.88, belongs to the moderate pollution..

TABLE 4 K1 DRILLING CALCULATION RESULTS OF HEAVY METAL POLLUTION IN DIFFERENT EVALUATION METHODS

Element	Cd	As	Cu	Ni	Pb	Cr	Zn	Hg
Average of enrichment coefficient	2.79	0.78	1.07	0.75	1.68	0.69	1.12	3.49
maximum of enrichment coefficient	4.28	1.28	1.62	1.02	2.16	0.93	1.51	5.70
Index of Geoaccumulation	0.9 (0-1)	-0.94 (0)	-0.49 (0)	-1.00 (0)	0.16 (0-1)	-1.12 (0)	-0.42 (0)	1.22 (1)
Nemerow index	3.61 medium	1.06 slight	1.37 medium	0.9 no	1.93 slight	0.82 no	0.46 no	4.73 medium
Ecological risk index	251.1							
Pollution load index	1.88							

Conclusion

The results of metal pollution degree, Index of Geoaccumulation and Nemerow index evaluation are low, but Index of Geoaccumulation seems to be lower. The whole K1 columnar samples show that the pollution *status* of Yalu River mouth is not serious. Most the heavy metals are natural sources by judgment of heavy metal content and coefficient of variation of K1 columnar samples, element (As and Hg) may have a small amount of the impact of human activities[2,11,12].

More methods are not obvious to the evaluation results of the environment pollution, but the evaluation result is the same with different parameters and formula. Mutual verification results show that the degree of the moderate pollution is credible.

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